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NASA CASE NO. LAR 14918-1 9

PRINT FIG. n/a

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Serial No.: 08/096,498  
08/16/93

LaRC

(NASA-Case-LAR-14918-1) NONAQUEOUS  
SLIP CASTING OF HIGH TEMPERATURE  
CERAMIC SUPERCONDUCTORS USING AN  
INVESTMENT CASTING TECHNIQUE Patent  
Application (NASA) 9 p

N94-15881

Unclass

G3/31 0190859

AWARDS ABSTRACT

**NONAQUEOUS SLIP CASTING OF HIGH TEMPERATURE CERAMIC  
SUPERCONDUCTORS USING AN INVESTMENT CASTING TECHNIQUE**

Previous ceramic casting methods involve placing a ceramic powder in water to form a slip which is placed in a plaster of Paris mold to remove the water from the slip leaving the ceramic article. Some ceramic powders, including high-temperature superconductors, are chemically unstable in water, making this process unsuitable for casting articles from these water-sensitive ceramics.

A process is provided for slip casting ceramic articles that does not employ parting agents and affords the casting of complete, detailed, precision articles that do not possess parting lines. In this method, the slip is formed by dispersing a ceramic powder in an organic liquid. The slip is poured into a mold made from a mixture of a calcium sulfate-bonded investment material of calcinated silica and fiberglass. This mold removes the organic liquid from the slip, leaving the ceramic article which is fired to provide a complete, detailed, precision, high temperature superconductive ceramic article without parting lines. The casting technique may take place in the presence of a magnetic field to orient the ceramic powders during the casting process.

The novelty of this method is found in providing a casting method for producing ceramic articles which is especially useful when water-sensitive or high-temperature superconductor ceramic powders are being used.

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Serial No.: 08/096,498

Filed: July 16, 1993

NONAQUEOUS SLIP CASTING OF HIGH TEMPERATURE CERAMIC  
SUPERCONDUCTORS USING AN INVESTMENT CASTING TECHNIQUE

Origin of the Invention

- 5           The invention described herein was made jointly in the performance of work under a NASA contract and by an employee of the United States Government. In accordance with 35 U.S.C. 202, the contractor elected not to retain title.

10   Background of the Invention

1.   Technical Field of the Invention

- The present invention relates generally to investment casting of ceramic structures and more particularly to investment casting of high  
15   temperature superconductors.

2.   Discussion of the Related Art

- Slip casting is a ceramic forming technique used to produce both thin-walled and solid ceramics of complex shape. In this process, ceramic  
20   powders are dispersed in water (referred to as a "slip") and poured into a porous plaster of Paris mold. The pores in the mold remove water from the slip leaving a cast ceramic in the shape of the mold. Upon removal from the mold, the ceramic piece is heated to high temperatures to produce the final product.

- 25           However, high temperature superconductors are chemically unstable in the presence of water, which is generally used as the carrier liquid in slip casting. When alternative liquids are employed, the plaster of Paris molds are ineffective to remove the liquid causing nonuniform casting and poor separation of the cast piece from the mold.

Copper-oxide containing high temperature superconductor materials (e.g  $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ ) are anisotropic, which results in difficulties in producing the material with enhanced properties. Several approaches have been taken to overcome the anisotropic nature of these compounds including  
5 melt texturing and magnetic alignment. However, these techniques have only been applied to small specimens as research techniques and have not been coupled with forming processes to produce a useful product.

Some complex shapes of superconductive compounds have been produced by machining a plate or pellet of the material (generally produced  
10 by cold pressing powders and subsequently heat treating the specimen to form a dense material). However, the machining process compromises the mechanical integrity of the specimen. Machining techniques cause cracks to form along the surface of the structure. Additionally, property enhancement techniques cannot be combined with the pressing process,  
15 resulting in a randomly oriented final product, with no enhanced electrical or magnetic properties.

It is accordingly an object of the present invention to provide a casting method for ceramics.

It is a further object of the present invention to provide a casting  
20 method for water sensitive ceramics.

It is a further object of the present invention to provide a casting method for high temperature superconductors.

It is a further object of the present invention to provide a casting method which results in uniform casting of net shapes and improved cast  
25 separation characteristics.

It is a further object of the present invention to provide a casting method which will allow orientation techniques to be combined with the forming process.

Additional objects and advantages of the present invention are  
30 apparent from the drawings and specification that follow.

Summary of the Invention

This invention relates to an investment casting techniques for producing ceramic articles. This technique is especially useful for high temperature superconductors and water-sensitive ceramics. The process does not require the use of parting agents, and affords the casting of complete, detailed, precision ceramic articles that do not possess parting lines. A wax pattern is provided for a shell mold. A coating of an aqueous mixture of a calcium sulfate-bonded investment material of calcinated silica and fiberglass is applied to the wax pattern to a thickness of at lease 0.25 inches to form a coated wax pattern which is then dried and cured at a temperature of about 1000°F to vaporize the wax pattern. The aqueous mixture of the calcium sulfate-bonded investment material of calcinated silica and quartz comprises 28 parts of water for every 100 parts of calcium sulfate-bonded investment powder. The resultant shell mold of the calcium sulfate-bonded investment material of calcinated silica and fiberglass is cooled to room temperature. A nonaqueous ceramic slip made by dispersing ceramic powder in an organic solvent and dispersant mixture is poured into the shell mold and allowed to set up. The ceramic powder may be a high temperature superconductor such as  $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$  or a water-sensitive ceramic such as silicon nitride and the organic solvent may be acetone. When casting thin-walled ceramic structures, the excess slip is poured out after a ceramic shell of desired thickness has set up in the mold. Solid ceramic articles are produced by refilling the mold with slip until a solid piece is formed. The shell mold is peeled from the ceramic, and the high temperature superconductive article is fired to provide a complete, detailed, precision superconductive ceramic article without parting lines. To improve orientation of the grain structure of the high temperature superconductive compounds, the casting process is carried out in the presence of a magnetic field of 0.5 Tesla or greater.

Detailed Description of the Invention

The present invention describes an entirely new process for producing net-shape articles of high temperature superconductors by investment casting. The combination of organic carrier liquids, used to disperse high temperature superconductors, and foundry molds is a new concept. These foundry molds are produced from a material normally used for flask molding of non-ferrous metals. This material, a calcium sulfate-bonded investment containing calcinated silica and fiberglass, may be obtained as "909 Investment" from Ransom and Randolph (R&R) of Maumee, Ohio. This investment was found to draw liquid from a nonaqueous ceramic slip in a similar manner to the drawing of water by plaster. By unconventional use of this material as a shell mold (as opposed to its normally intended use as a flask mold) in the slip casting of superconductive ceramics, as opposed to non-ferrous metals, the desired objects of the invention are achieved. The investment material employed had the following composition: cristobalite (sintered silica quartz), approximately 35% wt., mulite (alumina/silica), approximately 35% wt., calcium sulfate, approximately 30% wt., and fiberglass fibers  $\leq 0.05\%$  wt.

According to the present invention, a lost-wax technique was used to create a shell mold, which had all the detail of the original wax pattern. "909 Investment" from Ransom and Randolph was mixed in the proportion of 28 parts of water to 100 parts of investment powder. This mixture was applied by brushing or daubing on the wax pattern to a thickness of 0.25 to 0.5 inches. After slow drying at room temperature, or in an oven at 200°F, the mold and wax were cured at 1000°F to vaporize the wax from the mold. The mold was then cooled to room temperature and used for slip casting.

A nonaqueous ceramic slip was provided by dispersing powders of a high temperature superconductive compounds, such as  $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ , in an organic liquid such as acetone. A dispersant, such as Menhaden fish oil, was used to prevent settling of the powders from the liquid. Other organic liquid/dispersant combinations could also be used. The slip was poured into the shell mold and allowed to set up to form either a thin-walled or solid article. Once the casting was completely dry, the mold was removed from the article by misting the outer mold surfaces with water. The investment material used becomes weak when wet, allowing it to be easily peeled away from the high temperature superconductive article without damaging the casting surfaces. When slips prepared using powders of  $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$  superconductors were used, castings were fired to approximately 1750°F to densify the material.

The high temperature superconductor compounds are anisotropic, meaning that the electrical and magnetic properties of the materials are dependent on the orientation of the individual grains. To produce a material with enhanced properties, the grains must be aligned through some type of orientation procedure. Additionally, the orientation procedure used must be combined with the forming process to result in the best properties in the final product. The casting technique described in this invention may be carried out in the presence of a magnetic field to orient the ceramic powders during forming of the net-shape, producing an article with c-axis oriented grains.

NONAQUEOUS SLIP CASTING OF HIGH TEMPERATURE CERAMIC  
SUPERCONDUCTORS USING AN INVESTMENT CASTING TECHNIQUE

Abstract of the Disclosure

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A process for slip casting ceramic articles that does not employ parting agents and affords the casting of complete, detailed, precision articles that do not possess parting lines. This process is especially useful for high temperature superconductors and water-sensitive ceramics. A  
10 wax pattern for a shell mold is provided, and an aqueous mixture of a calcium sulfate-bonded investment material is applied as a coating to the wax pattern. The coated wax pattern is then dried, followed by curing to vaporize the wax pattern and leave a shell mold of the calcium sulfate-bonded investment material. The shell mold is cooled to room  
15 temperature, and a ceramic slip, created by dispersing a ceramic powder in an organic liquid, is poured therein. After a ceramic shell of desired thickness or a solid article has set up in the shell mold, excess ceramic slip is poured out. The shell mold is misted with water and peeled away from the ceramic article, after which the ceramic is fired to provide a complete,  
20 detailed, precision, high temperature superconductive ceramic article without parting lines. The casting technique may take place in the presence of a magnetic field to orient the ceramic powders during the casting process.

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